National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 5-12

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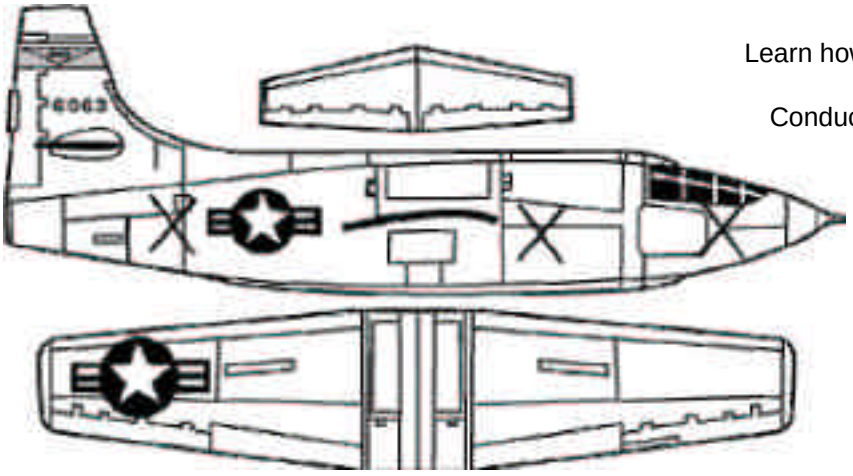
Educational Brief

The X-1 Paper Glider Kit: Investigating the Basics of Flight with a Model of the First Supersonic Aircraft



OBJECTIVES

The students will:
Build a glider.
Learn how to change the flight characteristics of a glider.
Conduct an experiment to answer a question.

STANDARDS AND SKILLS

Science
Science as Inquiry
Physical Science
Science and Technology

Mathematics
Measurement
Problem Solving

Science Process Skills
Making Models
Investigating
Predicting

BACKGROUND ON THE X-1 RESEARCH AIRCRAFT

The X-1 was the first in a series of rocket-powered research aircraft built for the US Air Force and NASA's predecessor, the National Advisory Committee on Aeronautics (NACA). Originally designated the XS-1 (for Experimental Sonic-1), it was built by the Bell Aircraft Company to break the alleged "sound barrier" and investigate the transonic speed range (speeds slightly below to just above the speed of sound). This was technological "no-man's" land at the time, as there were no research techniques or flight experience to duplicate it exactly.

The X-1 was not designed to take off under its own power, but was instead taken aloft attached to the bomb bay of a modified B-29 bomber. This fuel saving measure allowed for more flight time at test altitudes. Unpowered glide flights began early in 1946. On October 14, 1947, the X-1 with USAF Captain Charles “Chuck” Yeager as pilot, was air-launched at 21,000 feet. After a brief check of the four rocket motors, Yeager piloted the plane up to roughly 700 mph, becoming the first person to exceed the speed of sound (Mach 1).

The X-1 research program continued exploring transonic flight until 1951. The X-1 reached a maximum speed of 957 mph and an altitude of 71,902 feet. Modified versions continued flying until 1958. X-1 flights provided aerodynamic data never before available about the behavior of aircraft at transonic speeds.

The paper model glider depicts the second X-1 aircraft built, which was flown by the NACA from 1947-1951 (shown in the photographs that accompany this Educational Brief).

PAPER GLIDER ASSEMBLY AND FLIGHT TEST INSTRUCTIONS

Read directions and gather all tools before starting. You will need scissors, a sharp hobby knife and backup board, and a dull knife or butter knife. The X-1 Glider Template should be copied onto card stock or heavy paper. Use rubber cement for general construction and white glue for the tabs on the bottom wing panels and the stabilizer supports.

1. Cut out all parts on the outside lines.

2. Fold fuselage in half. Glue it together with rubber cement.

3. Use a hobby knife to cut the slot for the wing and horizontal stabilizer.
4. Slip wing through the slot. Center it in the fuselage.
5. Use a dull knife to lightly score the tabs on the left and right bottom wing panels. Fold them down.
6. Attach the left and right wing panels to the bottom of the wing with rubber cement. Be sure to keep the wing centered in the fuselage.
7. Glue the tabs to the side of the fuselage with white glue, and let dry.
8. Slip the horizontal stabilizer through the slot in the vertical stabilizer.
9. The stabilizer "supports" have tabs that are glued over the horizontal stabilizer to keep it straight. Look at the vertical stabilizer to see how the supports fit. The supports have tabs that must be folded up. Glue the supports to the vertical stabilizer, and glue the tabs to the horizontal stabilizer.

ADJUST THE CONTROL SURFACES

Modeling is a powerful tool that lends itself to all areas of scientific research. Your flying model X-1 is a research tool that you can use to conduct your own flight research project.

1. Test fly the X-1 as it is. How does it fly? Using rubber cement, add one set of left and right nose panels. Check X-1 for flight characteristics.

2. After your X-1 flies in a fairly stable glide, cut slits on the narrow sides of the control surfaces (ailerons, flaps, elevator, and rudder) to make them movable. Lightly score the hinge line of these control surfaces so they can be moved without bending the wing or stabilizers.

3. Start your research flight program. Change the position of the X-1's control surfaces to alter its attitude, glide path, roll, etc.

FLIGHT TEST SCENARIOS

Your inquiry-based kit is a special design. You need to determine how much nose weight is required for the X-1 to be properly balanced for stable flight.

Your airplane was designed for you to experiment with the balance point (center of gravity). This is the problem that you need to solve during the flight research program. It is the first step in the *scientific method*. We suggest you use the scientific method (outlined in the following) as a guide for your *research report.* This report may help you develop a science fair project.

Every aircraft has a center of gravity (CG). It is the point where the plane would balance if it were possible to suspend the plane at that point. As you will see during your X-1 flight research, the location of the CG strongly influences the way the glider flies.

FIND THE CG

Here is a simple way to find the approximate location of the glider:

1. Lay a pen on a table, then place the glider on top of it with the wings parallel to the pen.

2. Slowly roll the glider back and forth until you find the spot where the slightest nudge forward makes the nose drop, and the slightest nudge backward makes the tail drop. This is the balance point.

   Mark that it with the CG symbol:

This will serve as a reference point for further flight research.

MOVE THE CG

Place a paper clip or spring clip at the aircraft's CG symbol. Do a flight test and record what happens as you add more mass at the aircraft's CG.

Move the clip forward (toward the nose) of the CG mark, and measure this distance. Record the new flight characteristics.

Move the clip to the rear (toward the tail) of the CG symbol. Record the X-1's new flight characteristics. Each time you move the weight, you are moving the aircraft's balance point, or CG.

MOVE THE ELEVATORS

Experiment moving the elevators up and down to settings that make the plane glide the same way despite changes in the location of the CG.

What settings are needed when the CG is toward the nose? What settings are needed when the CG is toward the tail?

Are there CG locations that make the plane crash no matter how much you move the elevators?
If you were the pilot of an actual aircraft, where would you want the CG?

If you were designing an aircraft, would you give it elevators that could control the aircraft effectively at any CG location, or would you design the aircraft to have a limited range on the CG? What difference does it make?

Why is the CG important?

EXTENSIONS

Your Bell X-1 will never get near the speed of sound unless you take it on the Shuttle, the Concorde, or some other supersonic aircraft. But you will be able to test its flight qualities in *pitch*, *roll*, and *yaw*. You can also investigate *stall*, and its *glide ratio* (distance gliding forward/ height loss).

Consider how other flight researchers conduct their experiments. What tools are used for stability tests? How can you test your model for speed, distance, time aloft, angles, weight, surface area, center of pressure, and altitude gain? Can you think of any other data to record?

How does your model compare to the actual Bell X-1? How does it contrast? What is the scale factor between your model and the full-scale aircraft?

How does your X-1 fly compared to other gliders you've constructed?

Try making a larger scale model of the X-1. Add details and color to your model. Remember, it doesn't have to fly (that's just one aspect of modeling).

SCIENTIFIC METHOD

Scientific Method:

1. Define the problem.
2. Do background research. Sources include: parents, teachers, libraries, friends, and the World Wide Web.
3. Form a hypothesis (a prediction based upon knowledge).
4. Conduct experiments (test your predictions).
5. Form a conclusion. What is the difference between a conclusion and a solution?
6. Did your experiment lead you to discover an underlying principle or law?

One nice thing about your model is: if you exceed its structural limitations just build another. You will have learned from the first, and the second will be better. That's the way it works for everybody. Do something special as you work with your research aircraft.

"Research is to see what every one else has seen and to think what no one else has thought."
- Albert Szent Gyorgyi -

FOR FURTHER INFORMATION ON THE X-1

Suggested reading:

Ben Guenther (1988). *Bell X-1 Variants.* Arlington, TX. Aerofax, Inc.

Richard Hallion (1984). *On the Frontier.* Washington, D.C. NASA SP-4303.

Jay Miller (1988). *The X-Planes : X-1 to X-31.* Arlington, TX. Aerofax, Inc. ISBN: 0-517567490.

Louis Rotundo (1994). *Into the Unknown*. Washington, D.C. and London, England. Smithsonian Institution Press. ISBN: 1-56098-305-1

ON-LINE

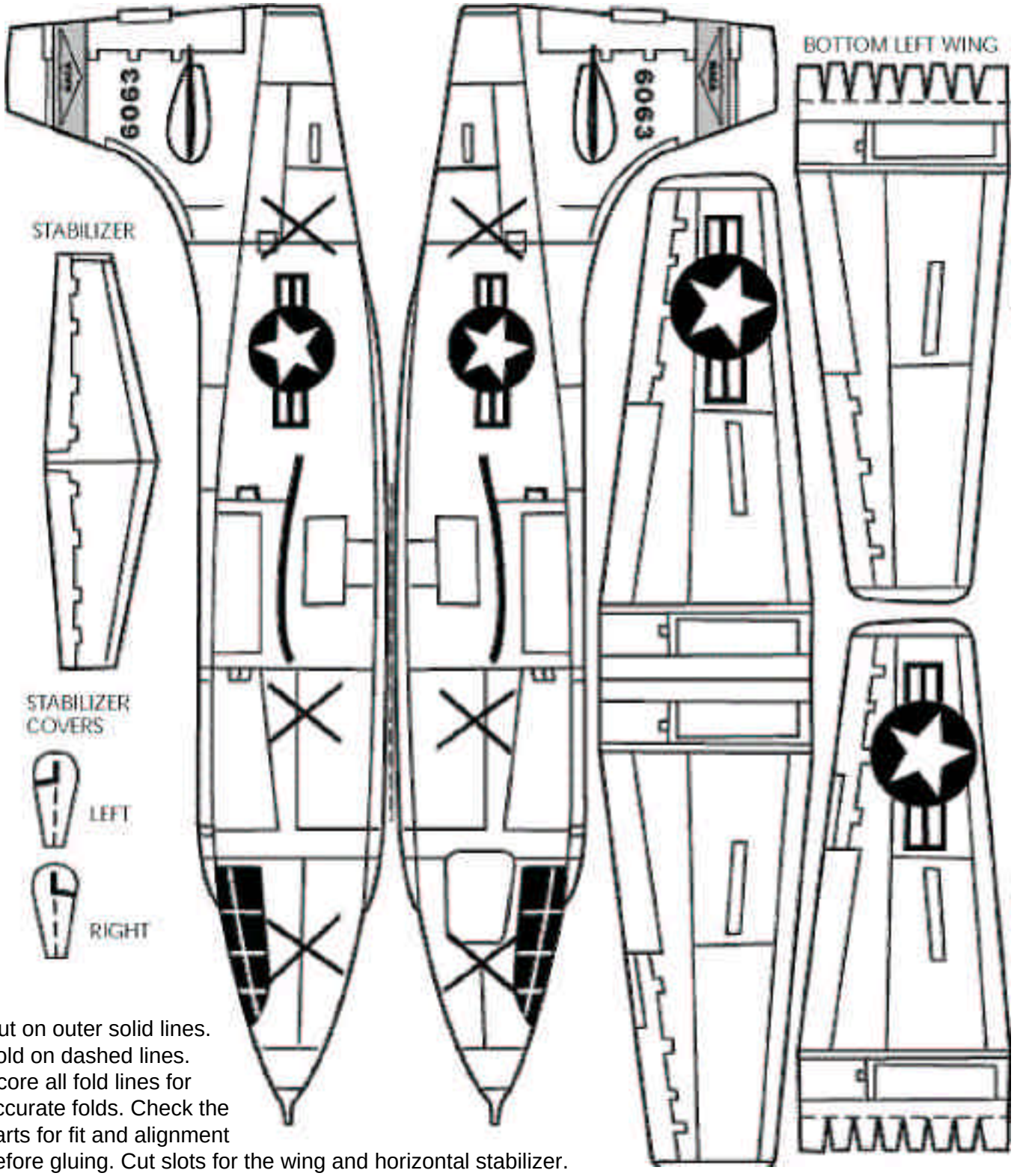
Learn more about NACA and NASA aeronautics at these websites:

NASA Dryden Flight Research Center
http://dfrc.nasa.gov

NASA Aerospace Technology Enterprise
http://aero-space.nasa.gov

This Educational Brief and other glider kits are available on Spacelink, the "electronic library" for NASA educational materials:

Spacelink
http://spacelink.nasa.gov



Cut on outer solid lines. Fold on dashed lines. Score all fold lines for accurate folds. Check the parts for fit and alignment before gluing. Cut slots for the wing and horizontal stabilizer. When cutting the fuselage, leave the left and right halves together at the fold line. Blue the halves together and cut out the fold line even with the fuselage.

X-1 Template